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Project Title: Developing range scenarios for high risk species

Project Category: Exotic Species

Rank by Organization (if applicable): 0

Total Funding Requested ($): 187,283 **Project Duration:** 2 Years

Abstract:

The spread of nonindigenous species (NIS) within and from the Laurentian Great Lakes challenges resource managers and policy makers to allocate monetary and personnel resources efficiently. Undoubtedly, effort is currently wasted on monitoring and controlling species that consititute a low risk of future spread, when effort would be better-spent fighting the same NIS elsewhere or a different NIS altogether. Thus, we propose to produce potential distribution maps for eight NIS that have or are likely to cause major ecological change. In this project, we will: 1) examine the strengths and limitations of the climate-matching approach by assessing how well native and current distributions are correlated with climatic boundaries; and 2) combine climatic and other variables important to each of the eight NIS to develop a set of map scenarios of the potential North American distribution for each species. Each scenario will be based on different assumptions about which factors limit range. We will produce broad-scale potential distribution maps based largely on climatic data for each NIS. We will determine more localized potential distributions by including other environmental and ecological factors that are suspected to limit the NIS. By producing a set of alternative scenarios for each NIS which may spread from, within, or to the Great Lakes we will clearly communicate scientific uncertainty, and help guide management plans for a variety of invasion possibilities. Results from this work will be applicable to all of the Great Lakes, and our approach could be applied to other problematic aquatic NIS elsewhere.

Geographic Areas Affected by the Project

States:

- [x] Illinois
- [x] Indiana
- [x] Michigan
- [x] Minnesota
- [x] New York
- [x] Pennsylvania
- [x] Wisconsin
- [x] Ohio

Lakes:

- [ ] Superior
- [ ] Huron
- [ ] Michigan
- [ ] Erie
- [ ] Ontario
- [x] All Lakes

Geographic Initiatives:

- [ ] Greater Chicago
- [ ] NE Ohio
- [ ] NW Indiana
- [ ] SE Michigan
- [ ] Lake St. Clair

Primary Affected Area of Concern: Not Applicable

Other Affected Areas of Concern:

For Habitat Projects Only:

Primary Affected Biodiversity Investment Area:

Other Affected Biodiversity Investment Areas:

Problem Statement:

The establishment and spread of nonindigenous species (NIS) is a growing problem globally, as well as in the Laurentian Great Lakes--with at least 141 NIS established at the present. Identifying recently-established NIS likely to spread widely would be important to resources managers and would aid in developing and prioritizing management plans to slow dispersal of NIS. Such information, for example, stimulated the development of management plans that appear to have slowed the spread of the zebra mussel Dreissena polymorpha within the U.S. Strayer (1991) predicted that zebra mussels could eventually spread from the Great Lakes to inhabit virtually the entire continental U.S. and much of Canada. He based this prediction on the climatic tolerances of zebra mussels in their natural range. Managers in states and provinces not yet infested with zebra mussels developed plans to prevent their establishment. Such efforts included formation of various state task forces and working groups, the production of television presentations and other educational materials (e.g., Colorado, Kansas, Montana, and Nevada), the regulation of transportation of zebra mussels (e.g., California, Nevada, and Washington), and inspection of boats entering the state (e.g., California). While these preventative measures are not a panacea, they were taken, in part, because of a compelling demonstration begun by Strayer (1991) that zebra mussels would be able to survive in broad expanses of North America not yet infested. The interdiction of zebra mussels at the borders of some of these states, and the continued lack of establishment of zebra mussels in western waters, suggest that these measures have prevented the establishment of zebra mussels in large western regions.

In North America, the distribution of zebra mussel has so far not greatly exceeded the range limits projected by Strayer (1991), except where they are established in waters that are unusually cold in otherwise very warm climates (e.g., the Mississippi River in southern Louisiana). Thus, for zebra mussel, the climate-matching approach was consistent with their Eurasian distribution, and seems to have offered solid guidance. This approach may produce less accurate predictions for the expanded ranges of species whose native ranges are constrained by factors other than climate. For example, this approach may have limitations for species whose ranges are severely limited by geographic barriers or biotic interactions (e.g., predation, competition) that do not correlate with climate.

For eight potentially high-impact NIS established in and around the Great Lakes, we propose the following. First, we will assess the strengths and limitations of developing scenarios of potential North American ranges based on similarity to native climate. We will do this by including in our study both species whose ranges we believe on the basis of preliminary information are primarily determined climatically, and species whose ranges we believe are constrained by dispersal barriers and biotic variables. Second, as appropriate for different species, we will combine climatic data with data on other range limiting factors to develop maps of potential North American range. Final products will consist of range predictions for each species of interest under alternative sets of assumptions about range-governing factors. Since the ultimate distribution of each NIS will depend on a number of factors, providing managers with a set of alternative range projections will communicate where uncertainty is greatest, and will maximize applicability of our predictions. The eight species chosen include species already spreading within the Great Lakes [ruffe (Gymnocephalus cernuus), round goby (Neogobius melanostomus), tubenose goby (Proterorhinus marmoratus), and rusty crayfish (Orconectes rusticus)], species that have already spread beyond the Great Lakes [spiny waterflea (Bythotrephes cederstroemi)], and species on the brink of invading the Great Lakes from adjacent drainages [Daphnia lumholtzi, silver carp (Hypophthalmichthys molitrix), and bighead carp (Hypophthalmichthys nobilis)].

Proposed Work Outcome:

Our reasons for choosing the eight NIS listed above are twofold: each has or is likely to cause ecological damage where it has been introduced; and the species differ in the likelihood that their native range is limited primarily by climatic factors. For example, ecological impact of the rusty crayfish, the species listed with the longest history of invasion around the Great Lakes, has been clearly demonstrated. Rusty crayfish eliminate macrophytes, reduce macroinvertebrates, and extirpate native crayfishes (Hill and Lodge 1999). The environmental impacts of the fishes on this list are not as well-studied as those for the rusty crayfish, but preliminary evidence suggests substantial current and future impacts. Ruffe, for example, quickly became the dominant fish taken in bottom trawls in the St. Louis River Estuary (Bronte et al. 1998), and may compete with yellow perch (Savino and Kolar 1997, Fullerton et al. 2000). Round goby quickly became established in all the Great Lakes and can impact macroinvertebrate communities and alter fish assemblages (Jude et al. 1995). Further, the predatory habits of B. cederstroemi, and the spiny morphology of both zooplankton species we will examine pose difficulties for fish ingestion (Kolar and Wahl 1998).

While the NIS we have chosen are all likely to cause substantial environmental change, they differ in the likelihood that climatic factors alone limit their distribution in their native range. Some of the chosen species have a large native range that is coincident with climatic boundaries, have a history of invasion into similar climates, and are thus excellent candidates for the climate-matching approach (e.g., ruffe, B. cederostroemi). The ranges of other species may be so tightly constrained by dispersal barriers that they inhabit only a small portion of the climatic region that is suitable for them. Examples include the mostly tropical-subtropical native distribution of D. lumholtzi, the threatened status of the tubenose goby throughout most of its rather restricted Eurasian range, and the rusty crayfish. The crayfish is native to the southern midwest (Indiana and Ohio), but has invaded substantially warmer (Kentucky, Tennessee) and colder (Lake Superior, Ontario) climatic zones. While climatic factors may partially limit the native range of these species, clearly other factors including dispersal barriers, are important. For these species, predictions of future range might be underestimates because the species can thrive in a greater range of climate than they currently occupy. Nevertheless, such range scenarios would be importnat partial guides to management. For other species--in which predators, competitors, mutualists, etc are important in determining the current range--the predicted future range could be smaller or larger than the eventually realized range. The inclusion of a variety of species in our study will allow us to explore the usefulness and limitations of the climatic-matching approach in general, and allow us to develop specific predictions for eight important species that should immediately be useful in management of these species.

Making predictions of broad-scale North American range for each NIS

We will begin to assess the potential North American range of each species by examining the climatic correlates of its native range. We will first obtain or construct a range map for each species within its natural range, drawing on as many published sources as necessary. We will then compare the range with climatic data available from sources such as the World Meteorological Organization (1998), which includes data from thousands of sites around the globe (e.g., 1961-990 for mean, maximum, and minimum monthly air temperature and precipitation, monthly mean days of ice cover, number of days with air temperature >10(C, and several other climatic variables).

We will conduct the same exercise for areas of each species' current range in which it is introduced. If the climatic correlates of those introduced areas are outside those of the native range, then we will know that the native range was not determined exclusively by climatic variables. We will therefore carefully assess other potential range-limiting factors, including dispersal barriers and interspecific interactions.

We will next identify at least 100 meteorological sites within and another 100 meteorological sites outside the natural range of each species, and compare climatic variables between the two site subgroups to identify apparent thresholds determining distribution within the species' current range. We will map the initial potential North American range of the NIS based on these climatic thresholds using GIS. Depending on thresholds determined above, several maps may need to be developed for some species, using different assumptions (i.e., prioritizing mapping effect of one climatic variable over another).

Making predictions about local-scale distributions for each NIS

Climatic variables may predict the broad-scale range of each NIS. Within this range, however, different water bodies will not be equally suited to establishment of a given NIS. Thus, to generate predictions about local-scale patterns of distribution, we will examine other factors that have been suggested to limit growth or distribution of each NIS, including pH, dissolved oxygen concentration, current velocity, and salinity for most species; calcium concentration, predator abundance, and likelihood of human introduction for crustaceans; and spawning habitat and water level for fishes, for example. Specific environmental and ecological variables to be considered for each species will be determined by a thorough review of available published literature regarding the biology and ecology of each NIS (see example of limiting variables in Table 1). The effects of two or more variables on distribution may be layered to produce a potential distribution influenced by several variables at different spatial scales. Similarly, the strength of impact a given variable may have on restricting the distribution of a NIS may be poorly understood, and a series of maps may be required to represent a range of possible impact strengths for a given variable.

Table 1. Variables of probable importance to the distribution of ruffe.

Variable	Threshold	Reference
Water velocity	Not specified; 'low velocity'	Winfield et al. 1998
pH	pH > 5 required for reproduction	Winfield et al. 1998
Water temperature	Range from 0-30 C	Ogle 1998
Salinity	6-9	Vetemaa and Saat 1996
Dissolved oxygen conc.	'needs well-oxygenated water'	Kovac 1998
Nutrients	More abundant in eutrophic systems	Winfield et al. 1998

Implications for policy and management of NIS

Tools are very limited in number for managers challenged to allocate monetary and personnel to control the spread of aquatic nuisance NIS in the Great Lakes region. By predicting the potential range of zebra mussels in North America, Strayer (1991) highlighted the likelihood for zebra mussels to escape the Great Lakes and become widely established. Management plans were put into action, and the spread of zebra mussels may have ultimately been slowed. Evaluation of this approach for a variety of NIS, and application of it where appropriate, would provide managers with important information regarding future NIS. By producing a set of potential distribution maps for these NIS spreading from, within, or to the Great Lakes using different sets of assumptions, we will communicate scientific uncertainty clearly, and provide tools to help address a variety of invasion possibilities. Because we will predict the potential North American distribution of the eight NIS proposed, our results will be directly relevant to all of the Great Lakes, and beyond. We use general principles not specific to the Great Lakes, and thus our general approach could be applied to other ecosystems and other invaders.

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Project Milestones:	**Dates:**
Project Start	07/2000
Ruffe & crayfish--complete models/maps	12/2000
Submit ruffe & crayfish manuscript	04/2001
2 zooplankters--complete models/maps	08/2001
Submit zooplankton manuscript	12/2001
Carps & gobies--complete models/maps	03/2002
Submit carps & gobies manuscript	06/2002
Project End	06/2002

☐ Project Addresses Environmental Justice

If So, Description of How:

☒ Project Addresses Education/Outreach

If So, Description of How:

We will make every effort during this project to communicate results so that they are accessible to front-line natural resource managers and policy makers. For example, in addition to technical publications on our range scenarios, we will attend meetings (NALMS, Midwest Fish & WIldlife, ANS) and write for outlets (Fisheries, LakeLine, Dreissena!, etc) that reach people in positions to make management and policy decisions.

Project Budget:

	Federal Share Requested ($)	Applicant's Share ($)
Personnel:	86,188	47,790
Fringe:	14,790	0
Travel:	14,568	0
Equipment:	6,000	0
Supplies:	6,120	0
Contracts:	0	0
Construction:	0	0
Other:	0	0
Total Direct Costs:	127,666	47,790
Indirect Costs:	59,617	0
Total:	187,283	47,790
Projected Income:	0	0

Funding by Other Organizations (Names, Amounts, Description of Commitments):

This project is part of a larger risk assessment effort on the transport, introduction, and spread of nonindigenous species in the Great Lakes. This project would assess over what geographic range the ecological impact of 8 given species (all potentially high impact) would be manifest. The tuition ($47,790) for a graduate student who will work on the project will be paid entirely by the University of Notre Dame. EPA funding (this proposal) would primarily support a postdoctoral fellow. This project builds on previous EPA and NSF projects on the spread and impact of rusty crayfish and on a current IL/IN Sea Grant project on the spread of rusty crayfish in the Great Lakes and its hybridization with native crayfishes. Other components of risk of NIS are being measured in different parts of the larger research effort.

An assessment of the likelihood of local establishment, spread, and impact of species would be assessed in my other pre-proposal in this competition. In addition, a proposal will be submitted requesting approximately $360,000 over 3 years from the Great Lakes Restoration Act (deadline 1 March 2000) and Great Lakes Fishery Commission (deadline 4 May 2000) to apply the theory of Population Viability Analysis (developed for endangered species) to estimate how the probability of establishment is related to the population size and identity of organisms in ballast water, ballast sediments, and fouling communities. Discussions toward this end have included Marg Dochoda, Chris Wiley, and Philip Jenkins. In addition, I will be submitting a proposal on 1 March 2000 to NSF's Biocomplexity program to focus an interdisciplinary group (including biologists, philosophers, economists) on integrating the various components of risk assessment for Great Lakes NIS. These coordinated efforts will advance prevention of NIS, and especially development of effluent standards for ballast water.

Description of Collaboration/Community Based Support:

See Education/Outreach and Other Sources of Funding sections